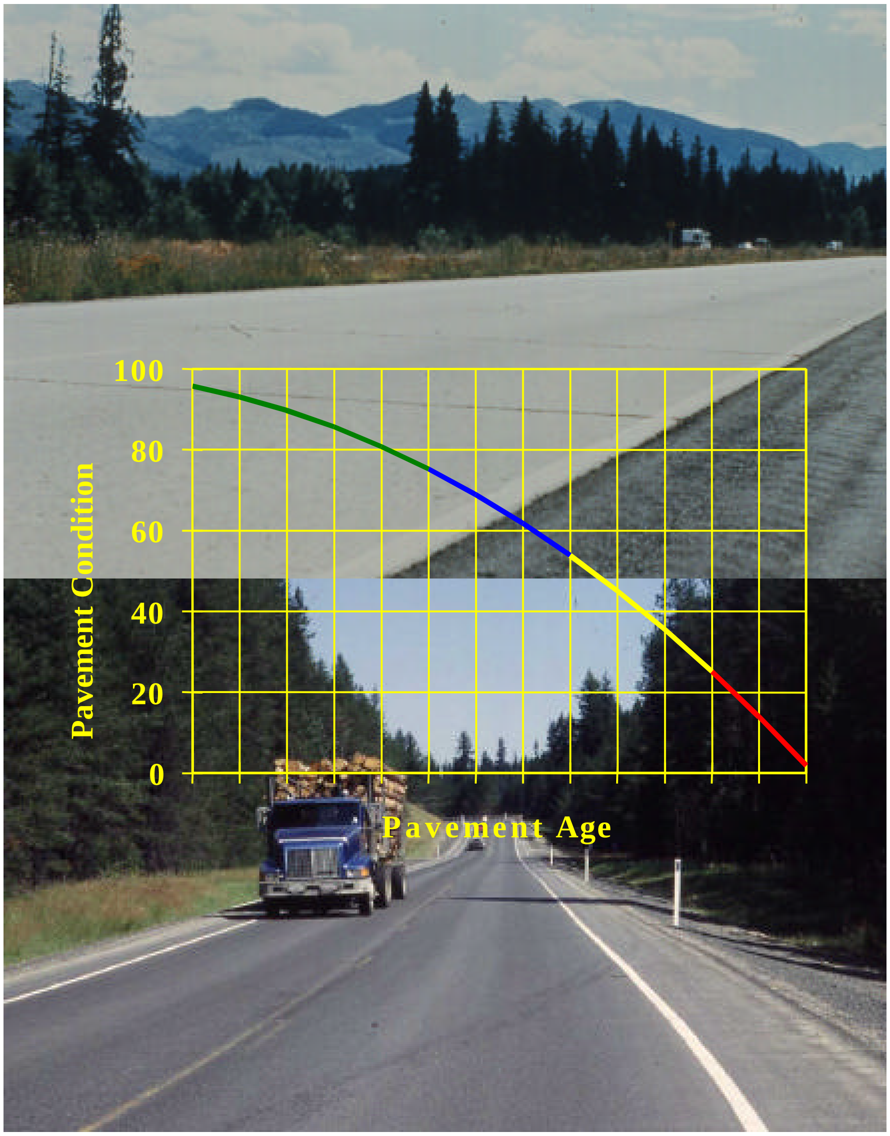
WASHINGTON STATE HIGHWAY PAVEMENTS



TRENDS, CONDITIONS, AND STRATEGIC PLAN

May 1999

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FOREWORD

What is a pavement? One definition of a pavement is layers of load-carrying material used for driving, riding and walking. More succinctly, a pavement is that surface we travel on. For the Washington State Department of Transportation (WSDOT) it is the 7,030 miles (17,900 lane-miles) of roadway surface that make up the State Highway System. WSDOT has a large investment in these pavements. This Plan is intended to provide significant information about the system to WSDOT decision-makers and technical staff.

This Plan not only reports on the current conditions and trends of the system, but also documents the agency's current pavement management approach and funding to support preserving and maintaining these pavements. The Plan lays out a strategic direction to address increased traffic loading, availability of new materials, methods, construction procedures, technology, and the need for continued customer focus. Periodic updates of the Plan will be prepared to document changes in the pavement system condition, trends and issues, and report progress on the action plans.

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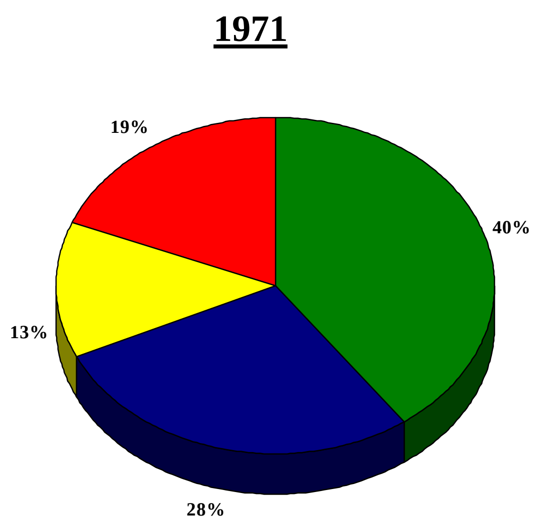
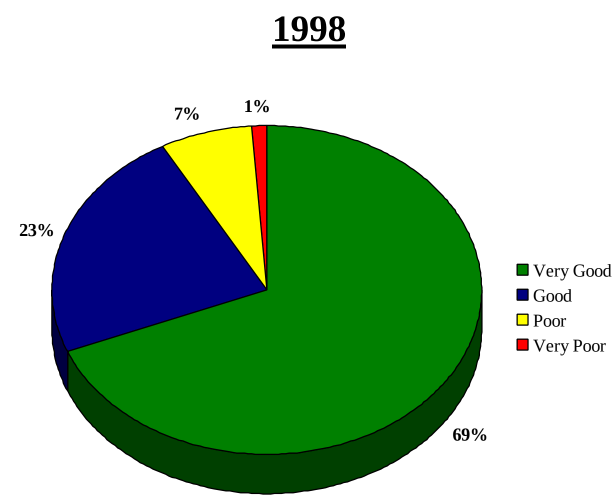
EXECUTIVE SUMMARY

The WSDOT route system accommodated 52 billion vehicle-miles of travel in 1997. This represents an increase of 85 percent during the last 20 years. This occurs on a pavement system of 17,900 lane-miles, which are surfaced with three types of materials: asphalt concrete (60 percent), bituminous surface treatment or "chip seals" (27 percent), and Portland cement concrete (13 percent).

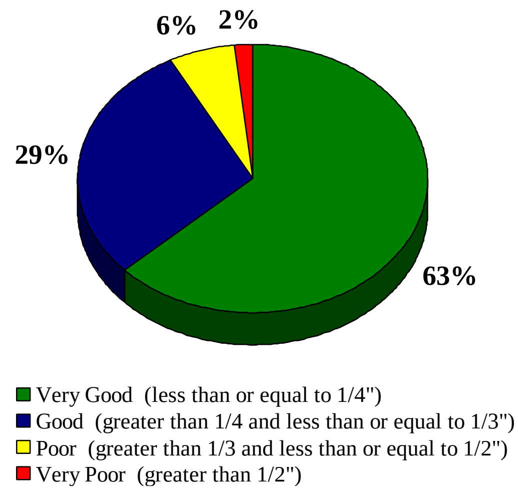
WSDOT manages the route system by monitoring all pavements to estimate when rehabilitation activities are required. This activity is a key element of the Highway System Plan Pavement Preservation Program. The data and analysis required to do this is termed the Washington State Pavement Management System (WSPMS). The WSPMS has evolved over a period of about 30 years. Initially, WSPMS was simply a listing of the condition of pavement segments on the WSDOT route system, but has become a process which uses the pavement condition information along with historical contract records, traffic counts, and information from other WSDOT data bases to predict the where, when, and what needed for pavement rehabilitation. The current condition measures include pavement distress, wheelpath rutting, roughness, and surface friction. Most often pavement distress such as cracking triggers pavements rehabilitation; however, excessive roughness, rutting, or low surface friction can as well. Specifically, three of the four pavement performance measures include:

- Pavement Structural Condition (PSC) which is a measure of pavement distress such as cracking and other distress measures and ranges from 100 (no distress or very good condition) to zero (extensive distress or very poor condition). WSDOT attempts to program rehabilitation for pavement segments when they are projected to reach a PSC of 50. Since the start of consistent monitoring of the WSDOT route system in 1971, the following PSC changes have occurred:

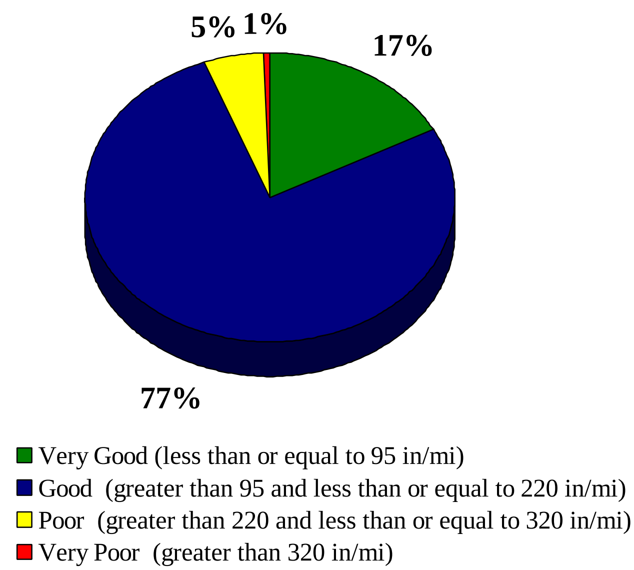




- Rutting in the wheelpaths is measured by rut depth. WSDOT attempts to program rehabilitation of pavements when the rut depths are projected to reach 1/3 inch. The ability to measure rut depth since 1971 has improved considerably but a historical comparison is not possible due to a change in the measurement procedure that occurred in the early 1990's. In 1998 the following rut conditions existed:



- Road roughness is measured by an index called International Roughness Index (IRI) and ranges from zero inches/mile (perfectly smooth pavement surface) to values in excess of 320 inches/mile (very rough pavement surface). In 1998 the following roughness conditions existed:



The WSPMS and the required information to support it continue to evolve. New equipment is being acquired to increase the collection speed and accuracy of pavement condition data. Further, the interaction between the Olympia Support Center (OSC) and the Regions has been improved by increasing the frequency of condition data collection, ease of access and processing. This is particularly important since all the decisions made under the Pavement Preservation Program are an interactive process between OSC and the Regions.

In 1998 WSDOT's highway programs were audited by the Joint Legislative Audit Review Committee (JLARC). The preservation program and the WSPMS were included in this audit. The findings of the audit indicate that the WSPMS satisfies least-life-cycle cost principles in its operation and forecasts times when pavements are due for rehabilitation. In the auditor's judgment, the process utilized by WSDOT in the development of its pavement rehabilitation priorities is a reasonable approach. The auditors found that highway users seem to be more sensitive to measures like roughness and rutting and therefore proposed that the WSDOT include pavement roughness in the candidate pavement project thresholds. The WSDOT does use roughness in consideration of asphalt pavements selection on a limited basis, and more so in the selection of Portland cement concrete pavements, especially due to slab faulting.

Current trends provide new challenges and demands. The number and weight of trucks continue to increase. Studded tires continue to produce significant wear of pavement surfaces. Traffic congestion has made the construction process more complicated and expensive. There are ever increasing demands to get more service out of our dwindling natural resources. The performance measures currently used are excellent measures of the route system's condition; however, a reexamination is in progress on the roughness of the route system. This will include a fuller understanding of the location and type of roughness (pavements, bridge decks, or bridge approaches).

This Strategic Pavement Plan identifies current practices and promotes action in areas of critical need for various aspects of the WSDOT pavement system. Specific action items are developed in the areas of:

- Pavement Design and Type Selection
  - Action: Evaluate new design procedures that improve pavement performance and reduce life cycle costs. Completion Date: Ongoing, staff is involved in national research and development programs.
- Pavement Rehabilitation
  - Action: Clarify the process for identifying and selecting pavement projects. (JLARC Recommendation 1). Completion Date: Completed and included in the 1999/2001 Programming Instructions.
  - Action: Continue to improve WSDOT's pavement assessment and design procedures for pavement rehabilitation. Completion Date: Ongoing, staff is involved in national research and development programs.
  - Action: Update Interstate urban corridor pavement rehabilitation to incorporate the dowel bar retrofit technology and to address issues for high volume urban areas. Completion Date: July 1, 2000.
- Pavement Management
  - Action: Improve the accuracy and timeliness of pavement condition data. Completion Date: July 1999.
  - Action: Improve the integration of roughness in the selection of candidate pavement project thresholds (JLARC Recommendation 2). Completion Date: The process using roughness for concrete pavements are currently in place, but will be evaluated in 1999-2000. Roughness on asphalt and bituminous surfaces will only be considered secondary to the structural and rutting needs. Generally WSDOT programs pavement

rehabilitation due to structure and rutting conditions much sooner than would be required due to roughness.

– Action: Periodically review the concept of “due” pavements and the progress towards achieving the least-life-cycle approach and to ensure that the observed asphalt concrete overlay lives are indeed moving toward the assumption of a 15 year life. Completion Date: Ongoing, review of the status of the system is based on the yearly collection of distress data.

- Pavement Maintenance

  – Action: Establish a maintenance management system that coordinates with the pavement management system (JLARC Recommendation 3). Completion Date: Pending Biennium Decision Package Approval.

- Construction Quality and Customer Relations

  – Action: Conduct a joint WSDOT/Construction Industry Workshop to identify and develop more “customer focused” approaches to highway construction. Completion Date: The workshop was held in Seattle on January 7-8,1999.

- New Technologies

  – Action: Continue to implement appropriate SHRP-related technology as it applies to pavements. Completion Date: Performance grade binder implementation beginning in 1999. Superpave implementations ongoing as developments occur.

  – Action: Utilize other pavement technologies as opportunities arise. Completion Date: South African high performance base courses scheduled for SR-395 in South Central Region in 1999/2001. Other technologies will be evaluated as opportunities and funding becomes available.

  – Action: Produce and maintain the Pavement Guide and related information on CD-ROM format that is accessible and useable by all. Completion Date: Latest update in July 1998, enhancements are ongoing.

- Funding

  – Action: Update the Highway Systems Plan when new pavement technologies present a change in resource needs. Completion Date: Every four years.

  – Action: Support continued funding of research for pavement issues. Completion Date: Pending Biennium Decision Package Approval.

Technical Annexes are included in the report that clarify and provide additional information for pavement design, preservation estimates, and research issues.

INTRODUCTION

The Washington State Department of Transportation (WSDOT) route system accommodated 52 billion vehicle-miles of travel during 1997. This amount of travel represents vehicle operating costs of about $23 billion to the traveling public. The WSDOT annual budget without the ferries, aviation, and state interest programs amounts to an expenditure of 1.9 cents per vehicle-mile traveled for a total of $900 million. Thus, WSDOT spends for pavements about one cent for every 30 cents spent by motorists for their vehicles. Based on national averages, every person travels about 30 miles per day (mostly on highways) for a total daily expense of about $15. If state highway pavements become rougher, motorists' vehicle operating costs will increase. Providing and maintaining pavements is expensive and important—both to motorists and WSDOT.

All hard surfaced pavements can be categorized into two groups: flexible and rigid. Flexible pavements are those which are surfaced with bituminous (asphalt) materials in the surface course (often referred to as the wearing course). These can be either in the form of pavement surfaces such as a bituminous surface treatment or asphalt concrete. A bituminous surface treatment is used on lower traffic volume roads (generally less than 2,000 vehicles per day) and asphalt concrete surfaces for higher traffic conditions. Rigid pavements are composed of a Portland cement concrete surface course. Asphalt surfaced pavements require resurfacing every 10 to 15 years; concrete pavements can last up to 30 years or more before major rehabilitation is required. Generally, it is quicker and less expensive to rehabilitate asphalt concrete pavements than concrete pavements but the rehabilitation does not last as long. There are tradeoffs with each.


Bituminous Surface Treatment Pavement


Asphalt Concrete Pavement

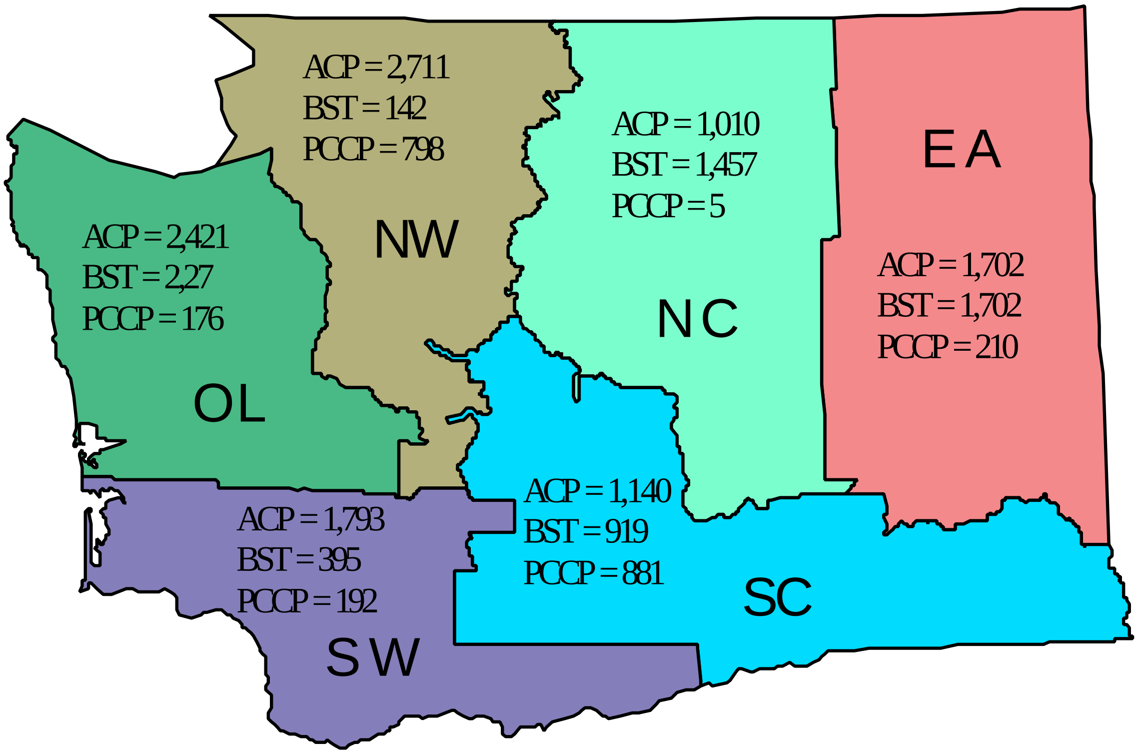
The WSDOT route system has about 17,900 lane-miles of pavements. A breakdown by pavement type includes:

- Asphalt Concrete Pavement:
  10,776 lane-miles (60% of network)
- Bituminous Surface Treatment:
  4,843 lane-miles (27% of network)
- Concrete Pavement:
  2,262 lane-miles (13% of network)


Concrete Pavement

Clearly the dominant surface type is asphalt concrete followed by bituminous surface treatments and Portland cement concrete. Further about 88 percent of the bituminous surface treatment pavements are in the three Eastern Washington Regions, along with 36 percent of the asphalt concrete pavements and 40 percent of the concrete pavement. Pavement issues also relate to the more than 3,000 bridges that are part of the aforementioned surfaces. Specific Regional pavement type mile values are illustrated on the following map.

WSDOT Regional Lane-Miles



SYSTEM CONDITION

Vehicle-caused pavement damage can be separated into autos with studded tires and trucks (due to axle loads). Studded tires are largely responsible for the grooves one sees in some of our high traffic asphalt concrete pavements. Further, after many years of wear, studded tires have even worn grooves in concrete slabs (particularly I-5 in the Seattle area and I-90 in Spokane).

Studded Tire Wear (left lane) and Truck rutting (right lane).

Trucks come into the picture via the loads placed on axles—the heavier the load, the more pavement damage. In fact, an approximate way to view this damage is called the fourth power law:

pavement damage $\cong$ (axle load ratio)^{4}

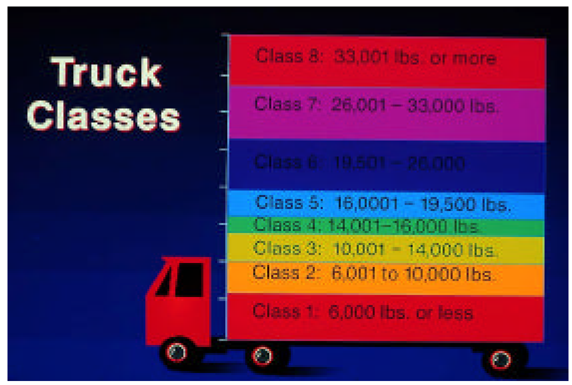
Thus, a truck axle loaded to 18,000 pounds as compared to the same axle loaded to 9,000 pounds would cause

$$\left(\frac{18{,}000 lbs}{9{,}000 lbs}\right)^{4} = (2)^{4} = 16 \text{ times}$$

more damage for only twice the axle load. This is one fundamental reason why heavier trucks pay more for annual licensing fees in this state (the State of Oregon uses a weight-distance tax for trucks). Pavement structures are designed to accommodate the expected truck traffic; therefore higher truck volumes result in thicker pavements.

The second major cause of pavement deterioration is related to climate effects. More specifically, it is the interaction of climate and traffic that can cause substantial pavement damage. Climate has a profound effect on pavement performance in all northern states due to ground freezing during the winter months followed by thawing. The part of Washington state primarily affected by this process is east of the Cascade Crest and thus includes the North Central, South Central, and Eastern Regions.

Pavement Damage and Trucks



Truck Class and Weight

Pavement Damage due to Climatic Effects

All inanimate objects subjected to repeated use, wear-and-tear, or loading cycles will fail eventually—unless some type of maintenance or rehabilitation process is performed. This is true of pavements as it is for commercial jet aircraft, buses, bridges, automobiles, railroads, locomotives, and so on. Typical <u>average</u> ages for some of the nation's transportation elements include:

- automobiles: 8 years
- commercial jet aircraft: 18 years
- commuter rail vehicles: 17 years
- urban buses: 8 years

Typically, the average age of a flexible pavement surface course is about eight years and that of a rigid pavement about 25 years (most of WSDOT's rigid pavements are on the Interstate system and these were mostly built during the 1960s and 1970s).

The oldest unrehabilitated pavement in the WSDOT route system is a short segment of SR 11 north of Burlington, Washington. Built in 1921, this concrete pavement is 78 years old (however, it has not experienced any significant, heavy traffic for many years).

SR-11, MP 8.46 – Oldest unrehabilitated Pavement in Washington State

WSDOT manages the route system by monitoring all pavements to estimate when maintenance or rehabilitation activities are required. This activity is a key element of the Highway System Plan Pavement Preservation Program. The data and analysis required to do this is termed the Washington State Pavement Management System (WSPMS). The WSPMS has evolved over a period of about 30 years. Initially, WSPMS was simply a listing of the condition of pavement segments on the WSDOT route system, but has become a process which uses the pavement condition information along with historical contract records, traffic counts, and information from other WSDOT data bases to predict the where, when, and what needed for pavement rehabilitation. Four fundamental measures are used as noted earlier:

- pavement distress (Structural Condition)
- wheelpath rutting (Rutting Condition)
- roughness condition (IRI)
- surface friction condition

Each measure will be briefly described.

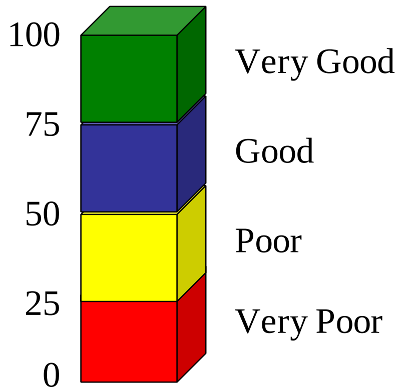
Structural Condition

Overall pavement distress is termed Pavement Structural Condition (PSC) and is calculated separately for flexible and rigid pavements. The PSC has an upper limit of 100 (no distress) and a lower limit of zero (extensive distress). The PSC is calculated based on the amount and severity of the following distress types:

<u>Flexible pavements</u>
- fatigue cracking (cracks due to repeated load cycles)
- longitudinal cracking
- transverse cracking
- patching

<u>Rigid pavements</u>
- slab cracking
- joint and crack spalling
- pumping and blowing
- faulting and settlement
- patching
- raveling and scaling

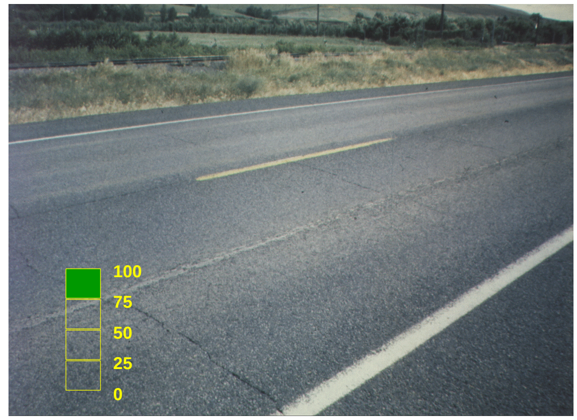
The PSC can be described by four broad pavement condition categories:

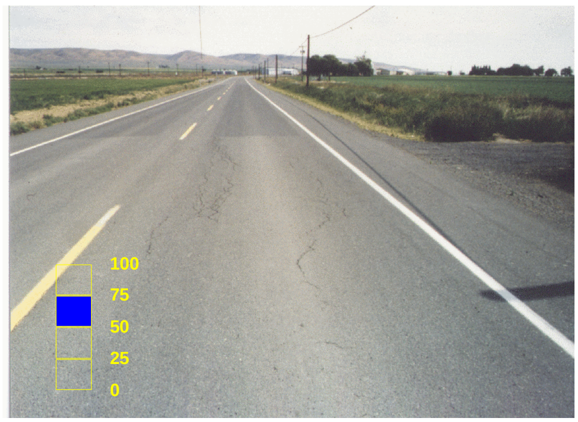


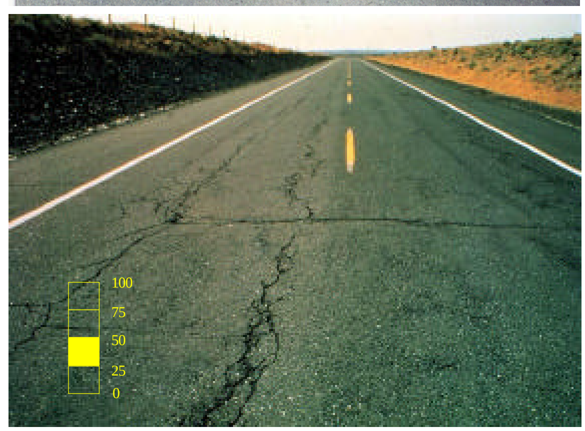
WSDOT attempts to program rehabilitation for pavement segments when they are projected to reach a PSC of 50. A PSC of 50 can occur due to various amounts and severity of distress. For example, a flexible pavement PSC of 50 is calculated when the wheel track has 25 percent of the length of the pavement segment experiencing fatigue cracking with "hairline" crack severity (this would represent the earliest stage of major structural deterioration).

For rigid pavement, a PSC of 50 represents 50 percent of the concrete slabs exhibiting joint faulting with a severity of 1/8 to 1/4 inch (faulting is the elevation difference at slab joints and results in a rough ride—particularly in large trucks). Further, a PSC of 50 can also be obtained if 25 percent of concrete slabs exhibit two to three cracks per panel.

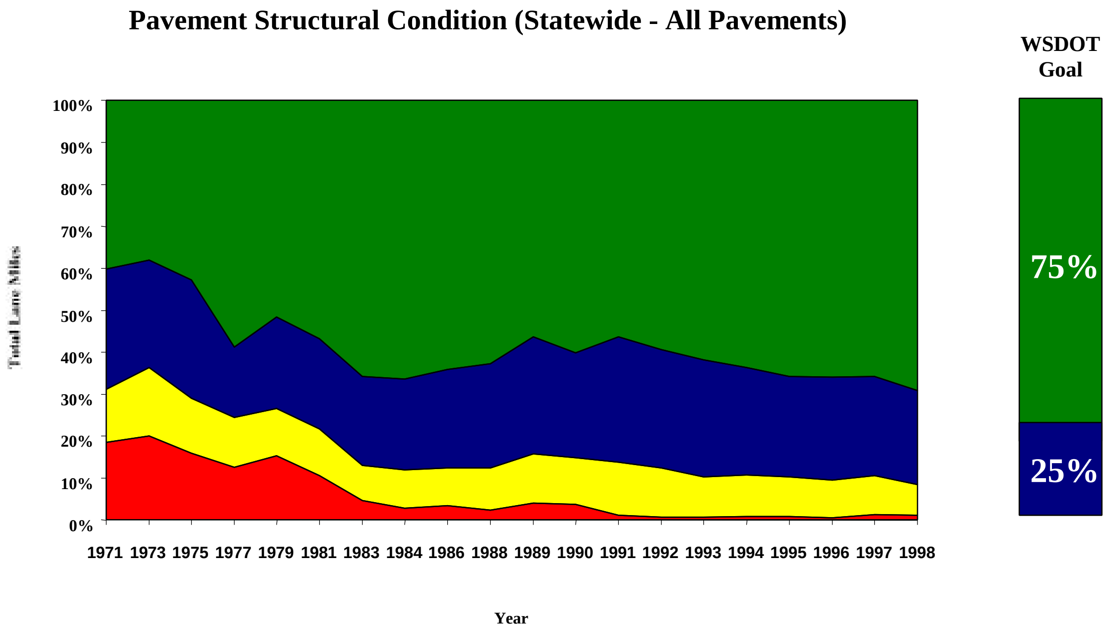
The illustrations on the right show the pavement condition for the four condition categories for an asphalt pavement.



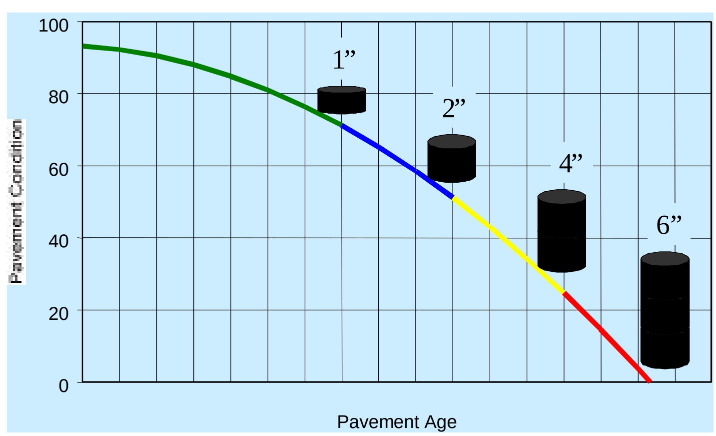




For all route classifications (Interstate, Principal Arterial, Minor Arterial, and Major Collector) the overall PSC are shown below from 1971 to 1998. It is notable how this condition measure has improved since 1971—noteworthy is the reduction of those pavements being in the very poor category from about 20 percent of the total lane-miles in the early 1970's down to about one percent in 1994 and later.



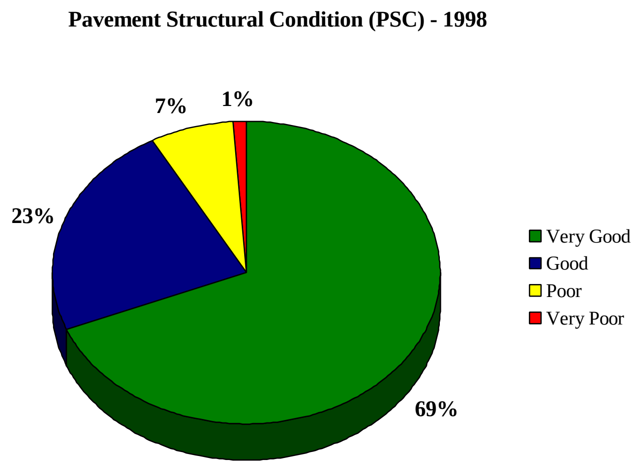
The concept of lowest life cycle programming proposes that the pavement structural condition will approach an optimal condition. This condition would result in an average statewide PSC value of about 81; there would be no "very poor" or "poor" pavement sections and the makeup of the system would be 25% "good" and 75% "very good". WSDOT is making progress towards this goal, albeit slowly.



Pavement Condition and Required Overlay Thickness

The figure above illustrates the required overlay thickness for the various ranges of pavement condition. As a pavement becomes more distressed (decrease in condition), an increase in pavement repair and overlay depths are required. The lowest life cycle cost is obtained by rehabilitating the pavement in the early stages of distress to reduce the need for extensive pavement repair and thicker overlays.

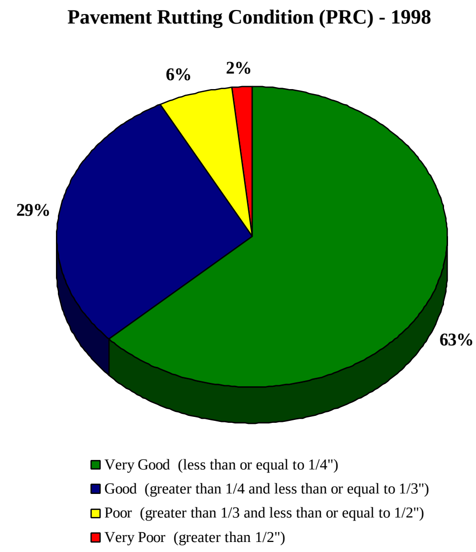
The illustration to the right further details the PSC breakout for the 1998 survey year.



Rutting Condition

A second condition measure is pavement rutting. This measure is used to estimate the depth of rutting or depressions in the wheel paths due to heavy traffic or studded tire wear. Ruts much deeper than 1/2 inch generally have the potential to hold water—a condition that may be hazardous for high-speed traffic.

The figure to the right shows the distribution of rutting for all of WSDOT's 17,900 lane-miles. The majority of WSDOT pavements have low rut depths, and hence are in good condition. Those sections in poor condition are in high traffic areas and are being addressed in current programs. WSDOT attempts to program rehabilitation of pavement segments when the rut depths are projected to reach 1/3 inch.

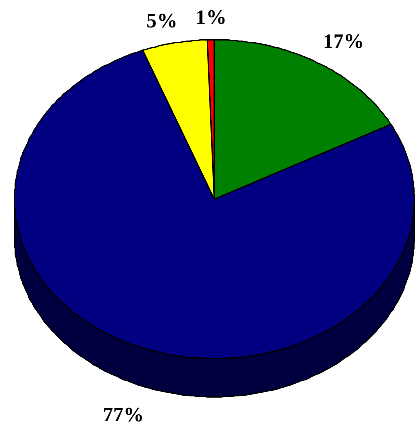


Roughness Condition

Pavement roughness is defined by the International Roughness Index (IRI). The IRI is calculated based on a measured road profile (WSDOT measures these profiles with laser sensors mounted on a van). The units of IRI are inches/mile. The following IRI ranges are used to define condition categories:

Roughness (IRI) (inches/mile)	Category	Typical Condition
Less than 95	Very Good	Smooth pavements
95 to 220	Good	Modest roughness; upper value noticeable to motorists
220 to 320	Poor	Older pavements; roughness quite noticeable, uncomfortable to truck drivers
Greater than 320	Very Poor	Very rough pavement; uncomfortable to all motorists

The figure to the right shows the IRI categories for the 1998 survey. WSDOT has been fairly successful in maintaining a relatively smooth route system as the percentages suggest. This is due, in part, to addressing pavement defects (such as cracking) early in their cycle, thus preventing significant roughness from occurring. WSDOT attempts to program rehabilitation for pavement segments when they are projected to reach an IRI of 220 inches/mile.



Surface Friction Condition

Surface friction is measured on the complete WSDOT route system every two years. In essence, a coefficient of friction is measured via a locked-wheel towed trailer (the actual value is called Friction Number). The friction of most dry pavements is high. Wet pavements are the problem. Thus, the Friction Number testing process involves application of water to the pavement surface prior to determination of the friction value. Such data allows WSDOT to identify potential low friction pavements that in conjunction with accident history and roadway geometrics are used to minimize wet weather skidding accidents.

LEGISLATIVE AUDIT

In 1998 WSDOT's highway program was audited by the Joint Legislative Audit Review Committee (JLARC). The pavement preservation program and the Pavement Management System were included in this audit. The findings and recommendations from the audit related to these two topics are as follows:

"**Findings**

1. *The WSDOT PMS assists in the development of the Pavement Capital Preservation Program. It satisfies least-life-cycle-cost principles in its operation, and forecasts times when pavements are due for rehabilitation. WSDOT managers and staff review these predictions and verify them through site visits, which also provide additional information needed to develop and prioritize projects. The Department's PMS has been applied to capital programming for several years, and in our judgment the*

development of the priority array in this way is a reasonable approach. Nevertheless, some technical issues should be addressed by the Department, as noted below.

2. *While trends in pavement condition according to PMS results are improving over time, the highway user survey conducted by JLARC in conjunction with this audit indicates at least some public dissatisfaction with pavement surface condition. Among five specific highway elements posed to survey respondents, road surface had the highest negative ratings, with 15 percent of respondents indicating an inadequate rating. Fourteen percent of respondents claimed that Washington's highways are either not as good as, or much worse than, other states' highways. While 57 percent rated state highways better than local roads and streets, 34 percent claimed they were about the same, and eight percent felt they are not quite as good, or much worse, than local roads and streets.*

3. *One reason for this difference in perception may be that the PSC, which is used by WSDOT as a key indicator of condition and need for future repair, is based upon cracking, whereas highway users are more sensitive to surface measures like roughness and rutting.[1] The PMS tracks roughness and rutting. With respect to roughness specifically:*

    - *Past research has shown that roughness is highly correlated with user perception of serviceability;*

    - *Ratings in the PMS (and data reported by Washington to Highway Statistics) show that that the state's pavements overall are only fair with respect to roughness; and*

    - *Roughness is the one measure that is not used as a threshold in the PMS for triggering consideration of a corrective project.*

4. *In reviewing data on the PMS and the pavement network, we noted a persistent set of approximately 1,000-2,000 lane-miles (of 18,000 total) in Poor condition. Whereas the percentage of Very Poor pavements has been reduced from more than 3,000 lane-miles in 1973 to almost none now, the population of Poor pavements has persisted since 1969 (i.e., these are not necessarily the same pavement sections, but rather a changing population whose quantity continues at a level between 1,500 and 2,000 lane-miles). There is no evidence to believe that these result from a defect in the PMS; rather, their existence appears to be the result*

[1] This finding derives from the AASHO Road Test in 1960 and subsequent research by state DOTs, which relates pavement serviceability, as perceived by users, to various measures of pavement condition. Serviceability is highly correlated with roughness and, to some extent, with rutting. Cracking exhibits the least correlation. Since only 2 percent of Washington's state highway network exhibits poor rutting, rutting may or may not be a key factor in this user perception of the state's highways.

of management decisions on which pavements will be rehabilitated in a biennium, and the Department must balance the reduction in this inventory of Poor pavements against the least-life-cycle-cost strategy applied to other pavements as they become due for rehabilitation. WSDOT staff indicate that the reduction in this backlog has been planned through a 12-year period, and progress in meeting this reduction can be monitored using the PMS.

Recommendations

1. *WSDOT should continue to take positive steps to clarify its process for identifying and selecting pavement projects. The Department should not only approve proposals now under consideration, but also put in place an action plan that monitors compliance with, and progress toward, implementing and applying these steps. Specific examples are cited below.*

2. *WSDOT should consider including pavement roughness, in addition to PSC and rutting, in its candidate pavement project thresholds.*

Examples of the clarification steps the Department can take to better communicate how it selects candidate pavement projects are the following:

- *WSDOT has proposed identifying pavement sections by specific pavement type and allowing only those corrective actions that are appropriate to that pavement type. This proposal should be approved, adopted, and monitored explicitly for compliance and follow-through by regions.*

- *WSDOT has proposed changes to the window in which pavement sections are due. This change should be revisited periodically in discussion with regions and the legislature to assess whether a more stable and easily communicated pavement program has indeed resulted from this change.*

- *While WSDOT now assumes a 15-year life in its pavement rehabilitation actions for asphalt concrete, field data show that actual lives now being achieved are less than 15 years. The current average pavement life for asphalt concrete pavements in Western Washington is 14.9 years and 10.5 years for Eastern Washington. This current situation can be explained by the transition in 1993 from a "worst first" approach to a "least life-cycle cost approach," coincident with the implementation of a changed capital programming process mandated by revisions to RCW 47.05. The recommendation here is to continue monitoring the distribution of pavement lives by region and statewide* *to ensure that observed pavement lives are indeed moving toward the 15-year assumption."*

WSDOT responses to the audit are incorporated into this plan.

STRATEGIC PAVEMENT PLAN

The preceding creates a background on the types of pavements used by WSDOT and indicates that these pavements are carefully managed—all positive aspects; however, current trends provide new challenges and demands. For example, the environment in which these pavements must serve continues to change. More specifically, this includes:

- **Loads.** The numbers and weights of trucks and buses continue to increase at a rate that accelerates the damage to pavements.

- **Studded Tires.** The use of studded tires produces significant wear in pavement surface courses resulting in increased maintenance and rehabilitation costs along with safety concerns (largely the increased potential for hydroplaning). Currently, certain types of paving mixes that reduce traffic-generated noise, splash, and spray cannot be used because of excessively high wear rates due to studded tires. Further, the higher the traffic speeds, the higher the rate of studded tire wear—a secondary effect of the recent increase in state highway speeds.

- **Construction and Traffic Congestion.** Construction on WSDOT Interstate highways has become very expensive and difficult. Traffic control and night time only work are significant costs in pavement rehabilitation projects. New and improved approaches are required to minimize inconvenience to motorists and keep construction costs reasonable.

- **Materials.** There has been pressure in the past to use pavements to dispose of waste materials such as old tires. For the most part, recycling such materials into new pavement layers does not add performance and generally increases construction costs. Further, WSDOT, like other road owning agencies in Western Washington, is finding quality, economical aggregate sources more difficult to obtain. Thus, the materials used in road building continue to present new challenges.

These kinds of issues require that pavement delivery systems undergo continuous improvement. There is strong evidence that this has been the case for many years. However, the recommendations and suggested action items in this Plan will further support this process.

Pavement Design and Type Selection

WSDOT makes use of state-of-the-art pavement design procedures. These procedures are contained in the American Association of State Highway and Transportation Officials (AASHTO)

Guide for the Design of Pavement Structures. The basic function of pavement design is to provide a structure which meets or exceeds the design life and accommodates the anticipated traffic loading, environmental conditions, available materials, and construction variability (for additional details on pavement structural design see Annex A). In order to ensure the proper selection of pavement type, the Pavement Type Selection Committee (based on WSDOT Directive D 21-02) is a critical element. This Committee is responsible for reviewing and approving all pavement type selections for newly constructed pavements and rehabilitated concrete pavements on interstate or principal arterial roadways that are two centerline miles or longer. Specifically, the Committee ensures that both flexible and rigid pavement types are fairly considered based on both engineering judgment and economic analysis.

Action Item

- Evaluate new design procedures that improve pavement performance and reduce life cycle costs.

  Responsible Organizations: Olympia Service Center Materials Laboratory

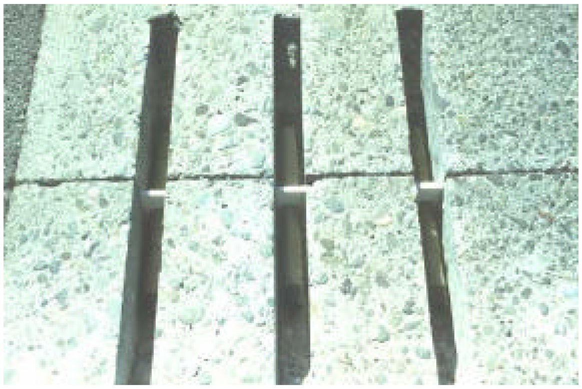
  Completion Date: Ongoing. Staff is involved in national research and development programs.

Pavement Rehabilitation

Pavement rehabilitation is required to extend the useful life of the existing pavement structure. For flexible pavements, WSDOT will continue to use advanced procedures (mostly nondestructive testing and analysis) for characterizing the existing pavement structure and for determining the amount and type of pavement strengthening that is required. For flexible pavements, the preservation policy is to protect the underlying pavement layers and rehabilitate only the surface course layer.

For rigid pavements, WSDOT is primarily rehabilitating mostly 30-year-old concrete pavements by increasing the strength of the pavement joints via retrofitting with steel dowel bars.


Placing an Asphalt Concrete Overlay


Dowel Bar Retrofit

This will extend the life of these pavements by ten or more years. WSDOT will continue to explore options for rehabilitating concrete pavements. The most recent plan for concrete pavement rehabilitation was completed in 1990. That plan must be updated to incorporate the dowel bar retrofit technology and to address issues for high volume urban areas.

Selection of appropriate treatments for existing pavements was an issue raised in the JLARC Audit because of a concern that inappropriate treatments were being used in an effort to meet target lane miles. It is important to note that an example of an “inappropriate treatment” as identified in the JLARC study could be placing a bituminous surface treatment over an existing asphalt concrete pavement surface. Though this may appear to be inappropriate, this practice has occasionally, though rarely, been done as a “holding action” to preserve the existing surface until a more complete, though expensive, asphalt concrete overlay could be funded and placed. We do agree, however, that some past practices would appear to sacrifice pavement preservation for the benefit of minor capacity improvements. This practice has been eliminated with the onset of the present program structure of independent programs for Improvements and Preservation.

Action Items

- Clarify the process for identifying and selecting pavement projects. Consider identifying pavement sections by specific pavement type and program corrective actions that are appropriate to that pavement type. (**JLARC Recommendation 1**)

  Responsible Organizations: Regions and OSC Materials Laboratory

  Completion Date: Rehabilitation strategies appropriate for each pavement type has been determined. Any variation from those pavement types must be justified by changes in traffic or other conditions and approved by the OSC Material Laboratory. This requirement was included in the 1999/2001 Programming Instructions.

- Continue to improve WSDOT’s pavement assessment and design procedures for pavement rehabilitation.

  Responsible Organizations: OSC Materials Laboratory

  Completion Date: Ongoing. Staff is involved in national research and development programs.

- Update Interstate urban corridor pavement rehabilitation strategies to incorporate the dowel bar retrofit technology and to address issues for high volume urban areas.

  Responsible Organizations: Regions, OSC Materials Laboratory and OSC Program Management Office

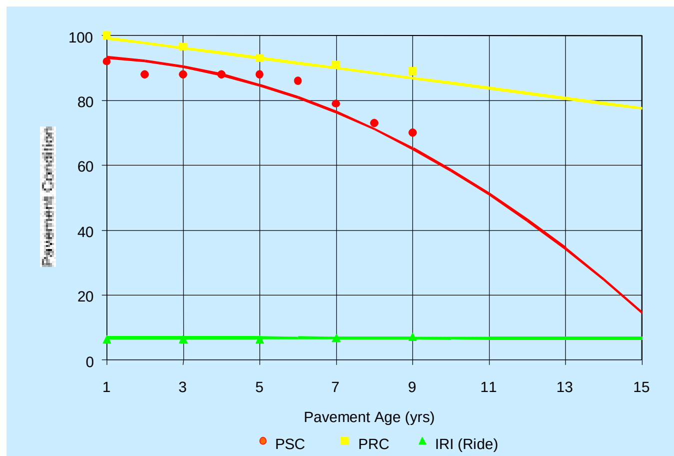
  Completion Date: July 1,1999.

Pavement Management

WSDOT was the first agency in the United States to fully develop and implement a pavement management system (PMS). This system has been, and continues to be the key element in the development of the Preservation Program and is used by both Regional and Olympia Service Center personnel. The significant feature of the system is to help determine the where, when, and what for pavement rehabilitation projects.

Pavement rehabilitation segments are identified which are projected to have critical, deficient pavement conditions. This list of pavement segments is generated using the PMS, which organizes information on the structure and condition of each section of pavement and applies analytic models (which yield performance curves) to predict the future pavement condition of each section.

After a roadway is built, its condition begins to deteriorate over time (refer to adjacent figure), due to traffic usage and environmental factors. While routine maintenance can lessen the rate of deterioration, it cannot stop it. Eventually the pavement requires rehabilitation. The condition at which rehabilitation should be performed is denoted by a threshold value of PSC (structure), PRC (rutting), or IRI (ride). These values are tracked in the PMS, and any threshold value can trigger the pavement section as a candidate for rehabilitation.

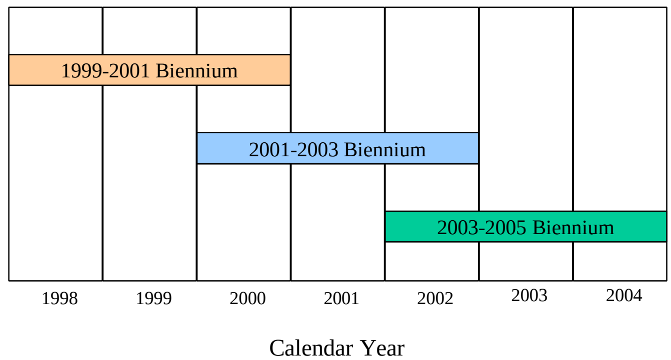


Example of an Asphalt Pavement Performance Curves

WSDOT has given careful consideration to the formulation and interpretation of the PSC itself, and the value of the PSC threshold, in terms of how pavement rehabilitation projects in Washington should be programmed. Cost analyses performed by WSDOT (using an earlier, but analogous, measure of pavement condition, the Pavement Condition Rating or PCR) show that unit costs of rehabilitation increase by a factor of three to four for projects programmed at a PSC of zero compared to projects programmed at a PSC of 40 to 50. Also, given Washington's climate, it is felt to be more efficient to rehabilitate pavements early (e.g., when the first stages of cracking have appeared), rather than later after the damage has progressed. Therefore, a PSC threshold of 50 is used to provide a least-life-cycle cost approach to pavement preservation along with a rutting threshold of 2/5 inch and IRI of 220 inches/mile.

Using the pavement condition and performance curves, the PMS can forecast the expected time to the next rehabilitation for each pavement section. Each candidate project is assigned to a priority group according to its predicted "due date." If rehabilitation is expected to occur in 1999, then the pavement section is "due" in 1999.

Projects due before the first construction season in the biennium being programmed (i.e., the first biennium of the investment program) are assigned to a priority group indicating that they are "past due" or part of a backlog, and are beyond the point at which the lowest life-cycle-cost solution can be applied. At the other end of the spectrum, projects due later than the third biennium in the future are all assigned to a single priority group that indicates they are beyond the six-year investment program period. Priority groups are defined by individual year only for those six years that are encompassed by the investment program. These priority groups, taken collectively, form the priority listing of pavement preservation needs.



Pavement "Due" Definition

The priority listing is a useful tool for OSC and the regions in developing the biennial preservation program. However, the list is supplemented by additional site visits to verify accuracy, assess causes of defects and determine abilities of the maintenance program to apply preventative or short term remedial treatments before a biennial program is developed.

In 1995 WSDOT turned its emphasis towards implementing a lowest-life-cycle cost approach that has as its goal the elimination of any pavements falling into the past due category. The program is now in transition with the majority of pavements being addressed when they are due. However, until the transition is completed, some miles will become past due before they are addressed. See Annex B for Projected Past Due Asphalt Concrete Pavement Lane Miles for 1999/2001 Biennium.

Action Items:

- Improve the accuracy and timeliness of pavement condition data.

  Responsible Organizations: OSC Materials Laboratory and Transportation Data Office

  Completion Date: July 1999. The acquisition of a semi-automated distress and profile data collection system (vehicle) occurred in February 1999. This vehicle will improve the accuracy of data and allow improved prediction of roughness for concrete pavement.

- Improve the integration of roughness in the selection of candidate pavement project thresholds. (**JLARC Recommendation 2**)

Responsible Organization: OSC Materials Laboratory

Completion Date: The process using roughness for concrete pavements are currently in place, but will be evaluated in 1999-2000. Roughness on asphalt and bituminous surfaces will only be considered secondary to the structural and rutting needs. Generally WSDOT programs pavement rehabilitation due to structure and rutting conditions much sooner than would be required due to roughness.

- Periodically review the concept of “due” pavements and the progress towards achieving the least-life-cycle approach and to ensure that the observed pavement lives are indeed moving toward the assumption of a 15-year life.

Responsible Organization: OSC Materials Laboratory

Completion Date: Ongoing. Review of the status of the system is based on the yearly collection of distress data.

Pavement Maintenance

Maintenance of the state’s roadways must include activities that sustain certain desirable pavement characteristics, such as;

- a smooth, quiet surface for safe and comfortable travel
- adequate skid resistance, to provide proper traction
- density sufficient to be waterproof and prevent damage from freezing and thawing cycles

Ideally, the maintenance of pavement should be accomplished with minimum expense and with the least possible traffic disruption. This maintenance should be looked upon as an investment to protect the pavement from costly renovation or reconstruction. Usually maintenance will occur at isolated locations along a roadway section. Early detection and repair of surface defects can save considerable labor, equipment, material costs, and ensure expected pavement performance.

Placing a Chip Seal

Patching

Action Item

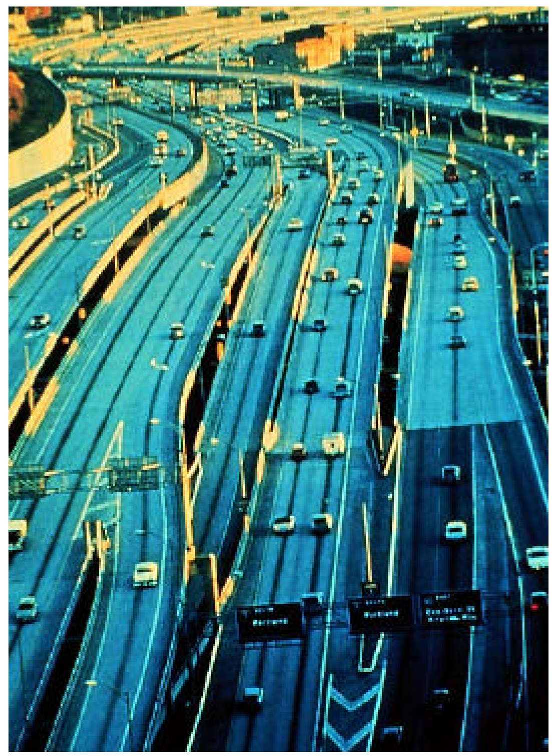
- Establish a maintenance management system that coordinates with the pavement management system. (**JLARC Recommendation 3)**

  Responsible Organizations: OSC Maintenance Office and Materials Laboratory

  Completion Date: Pending 1999/2001 Biennium Decision Package Approval

Construction Quality and Customer Relations

It is imperative that the construction process be more customer focused and based on up-to-date, rational specifications and practices. Construction deficiencies can quickly undo a well-designed project resulting in a substantial loss in pavement performance. Quality will be achieved in part by continuing to work closely with contractor associations. These associations have been valuable contributors to the sensible development of new procedures and practices. The staffing, training, and equipping of WSDOT project inspectors are critical in achieving a quality construction process.



I-5 Downtown Seattle - Southbound

During construction, the contractor is responsible for quality control. Although WSDOT's inspectors will perform sampling and testing to establish the quality of the materials, these tests will not be considered the sole means of quality control on the project. They are a statistical representation of large quantities and do not afford the contractor sufficient information to make adjustments in production. The contractor must manage a quality control effort independent of the State's testing.

Under current specification requirements, the contractor must make the decision to correct deficiencies in material production to increase pay factors (or to shut down production until the correction is made.) Regardless of the contractor's responsibilities in the QC/QA mode, the inspector will be included in the interpretation, significance, and administering of the test results.

Highway congestion and safety are causing motorists to become increasingly vocal and frustrated about not having full use of the highway system at all times. Calls to hot lines, project offices, legislators, e-mail messages, and abusive behavior to workers in the field reflect this increasing frustration.

New approaches and refinement of existing procedures are needed in highway construction and maintenance practices. A more customer friendly approach is required and should include the following:

- Improved coordination and project programming of all construction work in a corridor to minimize traffic disruptions and delay.
- Continued research and evaluation of new and innovative approaches to paving that improve the quality of the product and provide better performing pavements.
- Improved credibility and safety through accurate and effective communications such as appropriate public information plans; signs that match work zone conditions; faster setup and removal of traffic control at the start and end of work shifts.
- Increased use of innovative contracting techniques that place more responsibility on the contractor to lessen the time for lane closures and delay to motorists.

Action Items

- Conduct a joint WSDOT/Construction Industry Workshop to identify and develop more "customer focused" approaches to highway construction. Workshop topics should address the following issues:
  - Inform decision makers about ongoing pavement issues.
  - Improve the public's accessibility to information concerning construction related issues.
  - Coordinate project programming of all construction work in a corridor to minimize traffic disruptions and delay.
  - Improve public involvement during traffic control needs determination including noise impacts, business impacts, safety, congestion, and detour routes.
  - Evaluate and perform research, as appropriate, to implement new paving techniques that improve the quality of the product and provide better performing pavements.
  - Implement contracting techniques that improve quality and increase the benefit to the public.

Responsible Organizations: Field Operations Support Service Center (FOSSC)
Assistant Secretary

Completion Date: Workshop completed January 1999

New Technologies

WSDOT has and will continue to be aggressive in selecting and using the best of national, international, and locally developed procedures and practices to design, build, and maintain economical pavements; however, the state highway system is not and will not be an "experimental playground" for unproven products and processes. Viable, innovative improvements that increase pavement performance and/or reduce costs without jeopardizing desired results will be incorporated. Due to changing conditions for WSDOT pavements such as increasing truck and bus loadings and aging pavement structures (most of WSDOT's basic pavement structures were put into place during a 20 year period starting in the 1950's), advancements in pavement testing and analysis, structural design, materials, construction equipment and procedures will be evaluated and tested when and where appropriate. Use of new pavement technology can be illustrated by examining some of WSDOT's current pavement practices. These include:

- The use of retrofitted dowel bars to extend the life of concrete Interstate pavements by ten or more years.
- The adoption of Superpave asphalt binder specifications.
- The assessment and adoption of the Superpave asphalt concrete mixture design system.
- Advanced pavement rehabilitation structural design methods.
- A technically sound pavement management system which is the envy of many state DOTs as attested to by the JLARC Audit findings.

Ongoing or future assessments will include:

- Use of microsurfacing
- Hot in-place recycling
- Resurfacing asphalt concrete with concrete
- Use of rapid reconstruction techniques and materials
- Use of more rut and wear resistant asphalt concrete mixes (Stone Mastic Asphalt – European Technology)

Through its cooperative relationships with academia, FHWA, and other states, WSDOT will make use of appropriate technology from other countries. Not only will WSDOT make the maximum use of national and international developments in new technology but will also team with other states as appropriate to share and increase the knowledge gained.

The WSDOT Pavement Guide, currently issued on interactive CD-ROM, will continue to incorporate new, improved pavement technologies.

A more detailed discussion of the individual pavement technologies is provided in Annex C.
Action Items

- Continue to implement appropriate SHRP related technology as it applies to pavements.

  Responsible Organizations: Regions and OSC Materials Laboratory

  Completion Date: Superpave implementation schedule is provided in Annex C. Performance grade binder implementation beginning in 1999. Superpave implementation ongoing as developments occur.

- Utilize other pavement technologies as opportunities arise.

  Responsible Organizations: Regions and OSC Materials Laboratory

  Completion Date: South African high performance base courses scheduled for SR 395 in South Central Region in 1999/2001. Construction of a Stone Mastic Asphalt overlay on SR-524 Lynnwood in 1999 and possibly on I-90 in the vicinity of Ritzville in 1999/2001. Other technologies will be evaluated as opportunities and funding becomes available.

- Produce and maintain the Pavement Guide and related information on CD-ROM format that is accessible and useable by all.

  Responsible Organizations: OSC Materials Laboratory

  Completion Date: Latest update July 1998. Enhancements are ongoing.

- Conduct research to establish a methodology for reviewing, evaluating and implementing applicable pavement technology developed by other states or countries.

  Responsible Organizations: OSC Materials Laboratory

  Completion Date: This research will occur during the 1999/2001 biennium and is being conducted as a WSDOT research project with the University of Washington.

Funding

Adequate funding is essential if WSDOT is to maintain its pavements efficiently at the lowest life-cycle cost. This includes sufficient funds for new construction, preservation, maintenance, and research.

A key element in developing pavement preservation budget scenarios is RCW 47.05 "Priority Programming For Highway Development." In place since 1969, this law (and its modifications) has been the key in directing WSDOT toward objective and effective pavement preservation and a world leader in pavement management. The goal of Pavement Preservation funding is to maintain or restore the structural capacity of the pavement. This funding need is based on results of the WSPMS that takes into account the actual pavement conditions by Region, functional classification, and pavement type. These needs are included in the 1997 State Highway System Plan as adopted by the Transportation Commission. Two and six year funding levels are established in accordance with the System Plan projections.

The research and development activities noted in New Technologies requires consistent funding. Though research is a small part of the overall WSDOT budget, it is critical for examining and developing the technologies required in the future. The budget related items for pavements is developed within WSDOT, approved and/or modified by the Transportation Commission, and approved and/or modified by the Legislature. Refer to Annex B for additional information on projected pavement preservation funding requirements and the assumptions and methodology used in their development.

Action Items

- Update the Highway Systems Plan when new pavement technologies present a change in resource or funding needs.

  Responsible Organizations: Highways and Local Roadways Division

  Completion Date: Every four years

- Support continued funding of research for pavement issues.

  Responsible Organizations: Research Office lead with Budget and Programming Group support

  Completion Date: Pending Biennium Decision Package Approval

SUMMARY

WSDOT manages the route system by monitoring all pavements to estimate when maintenance or rehabilitation activities are required. These measures include pavement distress, wheelpath rutting, roughness, and surface friction. Most often pavement distress such as cracking triggers pavement rehabilitation; however, excessive roughness, rutting, or low surface friction can as well.

- Overall pavement distress is termed Pavement Structural Condition (PSC) and is calculated separately for flexible and rigid pavements. The PSC has an upper limit of 100 (no distress) and a lower limit of zero (extensive distress). WSDOT attempts to program rehabilitation for pavement segments when they are projected to reach a PSC of 50. A PSC of 50 can occur due to various amounts and severity of distress.

- Pavement rutting is a measure used to estimate the depth of rutting or depressions in the wheelpaths due to heavy traffic or studded tire wear. Ruts much deeper than 1/2 inch generally have the potential to hold water—a condition that may be hazardous for high-speed traffic. WSDOT attempts to program rehabilitation of pavement segments when the rut depths are projected to reach 1/3 inch.

- Pavement roughness is defined by the International Roughness Index (IRI). The IRI is calculated based on a measured road profile (WSDOT measures these profiles with ultrasonic sensors mounted on a van—the sensors are essentially industrial strength ranging sensors similar to those used on Polaroid cameras). WSDOT attempts to program rehabilitation for pavement segments before they are projected to reach an IRI of 220 inches/mile.

- Surface friction is measured on the complete WSDOT route system every two years. In essence, a coefficient of friction is measured via a locked-wheel towed trailer (the actual value is called Friction Number). The friction of most dry pavements is high. Wet pavements are the problem.

In 1998 WSDOT's highway programs were audited by the Joint Legislative Audit Review Committee (JLARC). The preservation program and the Pavement Management System were included in this audit. The findings of the audit indicate that the WSPMS satisfies least-life-cost principles in its operation and forecasts times when pavements are due for rehabilitation. In the auditor's judgment, the process utilized by WSDOT in the development of its priority system is a reasonable approach. The auditors found that highway users seem to be more sensitive to measures like roughness and rutting and therefore proposed that the WSDOT include pavement roughness in candidate pavement project thresholds. The WSDOT does use roughness in consideration of asphalt pavements selection on a limited basis, and more so in the selection of Portland cement concrete pavements, especially due to slab faulting.

Current trends provide new challenges and demands. The number and weights of trucks continue to increase. Studded tires continue to produce significant wear in the pavement surfaces. Traffic congestion has made the construction process more complicated and expensive. There are ever increasing demands to get more service out of our dwindling natural resources.

This Strategic Pavement Plan identifies current practices and promotes action in areas of critical need for various aspects of the WSDOT pavement system. Action items are developed in the areas of:

- Pavement Design and Type Selection
- Pavement Rehabilitation
- Pavement Management
- Pavement Maintenance
- Construction Quality and Customer Relations
- New Technologies
- Funding

Technical Annexes are included that clarify and provide additional information for pavement design, preservation estimates, and research issues.

Technical Annexes

ANNEX A

REQUIREMENTS FOR PAVEMENT DESIGN

New Construction

The characterization of existing subgrade soil is done via laboratory tests and/or nondestructive testing. Laboratory tests can include the determination of gradation, soil type (clay, silt, gravel, etc.), AASHTO soil classification, liquid limit, plasticity index, R-value, and resilient modulus. The resilient modulus is defined as the slope of the stress-strain plot within the plastic range. The resilient modulus is a measure of the materials stiffness and is not a measure of its strength.

Resilient Modulus Laboratory Test

Non Destructive Testing using the Falling Weight Deflectometer

Quality construction materials must be readily available. Selection of design options may be influenced by the cost of materials.

The environment has a significant impact on pavement performance. Some of the environmental considerations are frost (design total pavement thickness to withstand the effects of freeze-thaw), rainfall (requirements for drainage), temperature (concern with asphalt rutting and joint spacing in concrete pavements) and location of groundwater table (requirements for drainage).

Traffic loads are estimated and characterized according to equivalent single axle loads (ESAL). This method is used to convert wheel loads of various magnitudes and repetitions to an equivalent number of "standard" or "equivalent" loads for design purposes. An ESAL is equivalent to an 18,000-lb single axle load.

The design period is the length of time that a new or reconstructed pavement structure will last before reaching its terminal serviceability. WSDOT has established the following periods based on functional class for new pavement design:

- Interstate and principal arterial: 40 years
- Minor arterial and collectors:

ESAL > 100,000 per year use 40 years
ESAL < 100,000 per year use 20 years

Economic analyses are required for interstate and principal arterial highways with project lengths of two or more center line miles.

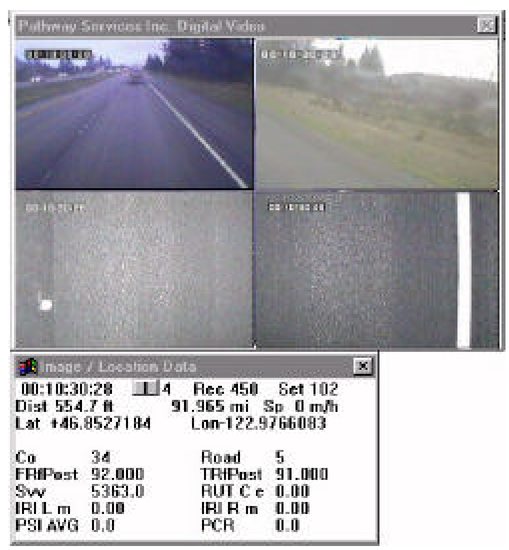
Rehabilitation

Distress Identification

Existing pavement condition – quantifying the condition of the existing roadway will provide an increased understanding of past performance. Knowing when and how a pavement distresses will inform the pavement designer of potentials for underlying base or subgrade problems, inadequate structure, insufficient material properties, increased truck loading, etc.

In 1999 WSDOT purchased a data distress collection van that records pavement profile (ride, faulting and rutting) and video images of the pavement surface, ahead view, and shoulder view. The following three images show the van, the required workstation(s) and a view of the images collected by the four video cameras. This data can be collected at highway speeds and will significantly enhance the accuracy of the data collection process as well as provide a variety of research and analysis options concerning pavement performance.


Pavement Condition Van



Camera Views

Workstation for Analyzing Pavement Condition

Flexible Pavements

WSDOT has developed, in conjunction with the University of Washington, a mechanistic-empirical overlay design procedure. This procedure incorporates the use of pavement deflections measured using a falling weight deflectometer, layered elastic theory (stress and strains), seasonal variations in the base and subgrade materials due to temperature, and truck loading (ESAL) to determine overlay thickness.

Evercalc – Backcalculation Program

Everpave – Mechanistic-Empirical Asphalt Concrete Overlay Design Procedure

Rigid Pavements

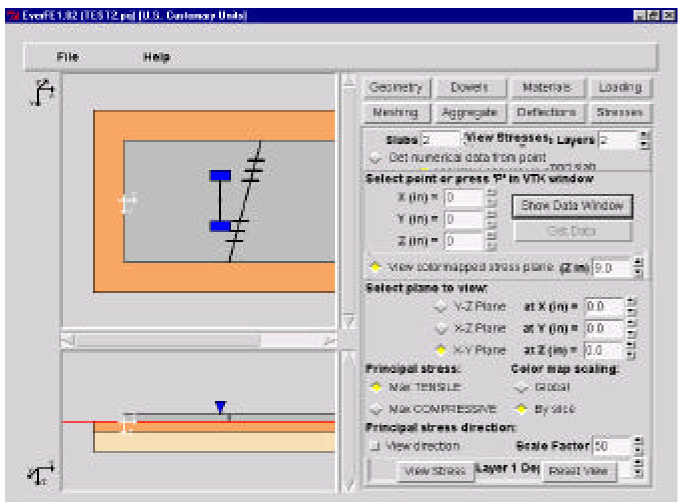
Concrete pavements in Washington State have typically out-performed the expected design periods. The concrete pavements constructed in the 1960's – 1970's were designed for a 20-year service life. Not only have these pavements reached ages of 30 to 40 years, but they have also carried anywhere from two to five times their design traffic loads.

Concrete Joint Faulting.

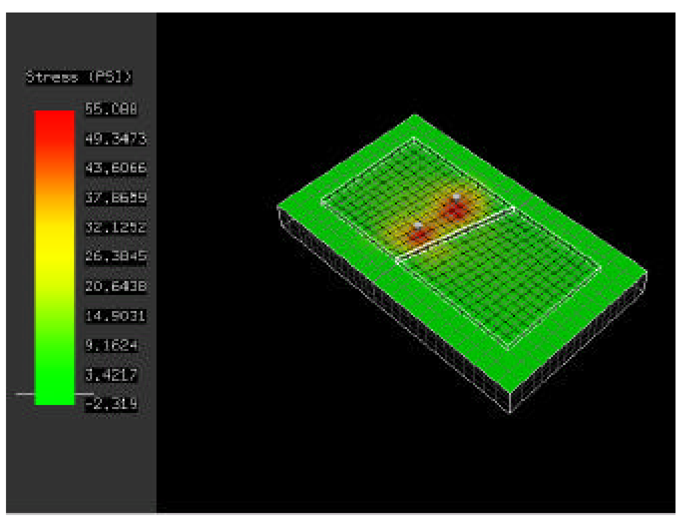
This exceptional performance, in large part, is due to good design and extremely hard aggregate. However, those concrete pavements are now in need of rehabilitation with high levels of joint faulting. Faulting is a step difference in adjoining concrete slabs.

For years, the only agreed upon rehabilitation was a thick asphalt concrete overlay. Performance of these overlays was satisfactory for a number of years until reflective cracking began to decrease the service life of the pavement. Currently, WSDOT is actively pursuing the use of load transfer restoration and diamond grinding to extend the life of concrete pavements. As future rehabilitation options develop, WSDOT will fully investigate and implement viable options as necessary.

In 1997, WSDOT received delivery of a three-dimensional finite element program that will significantly enhance the ability to investigate concrete performance and rehabilitation alternatives. The following illustrations show the main screen for the EverFE computer program and an example of the program results.



EverFE Computer Program



EverFE Results - Stresses

ANNEX B

PAVEMENT PRESERVATION ESTIMATE

Roadways require periodic resurfacing to keep the driving surface smooth and safe, and to prevent failure of the underlying sub-structure. WSDOT's policy is to resurface at the point of lowest life cycle cost. If resurfacing is done too early, pavement life is wasted. Resurfacing that is done too late requires additional costly repair work and increases the risk of failure of the underlying surface structure and very costly roadway construction. There is currently a backlog of pavement preservation needs that have gone beyond the point of lowest life cycle cost resulting in higher cost rehabilitation today. This pavement preservation plan is funded at a level that will achieve lowest life cycle paving while eliminating the backlog needs.

The Highway System Plan (HSP) is one element of the Statewide Multimodal Transportation Plan. This HSP specifically defines service objectives and proposes strategies for maintaining, preserving, and improving state highways. The HSP is important because it forms the basis for development of future state transportation programs, projects, and budgets.

The 1997 HSP Pavement Preservation Estimate was developed using 1997 unit costs for typical work and considered the present pavement condition of the entire network. The following pages are a summary of the Estimate information. Also included are various charts of information related to development of the Estimate.

DESCRIPTION OF THE PAVEMENT PRESERVATION ESTIMATE

Determination of Target Miles

Target miles are determined by multiplying (Region Total Target Miles, first Table, Page 35) times (Percent Total Miles, Middle Table, Page 34) times (Percent Due/Past Due, Last Table, Page 34). The target miles with or without PG binders will be the same for all Western Regions since it is not anticipated that PG binders will increase the expected pavement life. For Eastern Regions, the target miles with PG binders are reduced due to the increased cost for the modification of all binders in the Eastern Regions to PG binders (see second Table on Page 35).

Cost Estimate

The cost estimate is based on the average expected costs for the specified project (see tables on Page 33). Cost for the first cycle is the cost for the first ten years of the Plan, and the cost for the remaining years is the cost for the second ten years of the Plan. The twenty year costs is the summation of the first ten years and the second ten years of the Plan.

Past due repair costs are based on a percentage of the overlay cost depending on the length of time a project is past due. The repair costs are assumed to include costs for pavement repair or an increase in the overlay thickness.

Asphalt Concrete Pavement Estimate

This estimate is based on two regional areas (east and west sides of the state), four highway types (rural two lane, rural multilane, urban two lane, urban multilane, and ramps), and two project types (due and past due – refer to discussion on Page 15).

Portland Cement Concrete Pavement Estimate

This estimate is applied to all areas of the state on all highway types. The estimate is based on two project types (dowel bar retrofit and full replacement).

Bituminous Surface Treatment Estimate

This estimate is applied to all areas of the state on all highway (designated BST routes).

ACP Thin Overlay Estimate

This estimate is applied to all areas of the state on all highway types (designated routes).

Safety and Drainage Restoration

This estimate is based on 12 percent of the total costs for asphalt concrete pavement, Portland cement concrete pavement, and bituminous surface treatments.

Other P1 Costs

This estimate is includes those costs associated with weigh stations, research, pits and quarries, and the pavement management system.

Pavement Preservation Estimate
(From 1997 Highway Systems Plan)

Asphalt Concrete Pavement (ACP) Estimate

Region	Highway Type	Project Type	Target Ln-Mi[1] per Year	Target Ln-Mi[1] per Year w/PG	Cost per Ln-Mi	Cost for First Cycle[2]	Cost for Remaining Years[2]	20 year Cost
Western	Rural -	Due	210	210	$ 89,300	$ 204.2 M	$ 192.4 M	$ 396.6 M
	Two lane	Past Due	27	27	$ 119,800	$ 35.2 M	$ 0	$ 35.2 M
Eastern		Due	224	134	$ 80,700	$ 117.7 M	$ 150.0 M	$ 267.7 M
		Past Due	6	4	$ 107,800	$ 4.1 M	$ 0	$ 4.1 M
Western	Rural -	Due	45	45	$ 86,900	$ 42.3 M	$ 39.9 M	$ 82.2 M
	Multilane	Past Due	6	6	$ 114,400	$ 7.2 M	$ 0	$ 7.2 M
Eastern		Due	129	77	$ 78,300	$ 65.8 M	$ 83.8 M	$ 149.6 M
		Past Due	3	2	$ 105,800	$ 2.3 M	$ 0	$ 2.3 M
Western	Urban -	Due	27	27	$ 129,600	$ 37.9 M	$ 35.7 M	$ 73.6 M
	Two lane	Past Due	3	3	$ 163,500	$ 6.2 M	$ 0	$ 6.2 M
Eastern		Due	11	7	$ 101,300	$ 7.4 M	$ 9.4 M	$ 16.8 M
		Past Due	0	0	$ 135,200	$ 0.3 M	$ 0	$ 0.3 M
Western	Urban	Due	118	118	$ 110,800	$ 143.1 M	$ 134.8 M	$ 277.9 M
	Multilane	Past Due	15	15	$ 135,600	$ 22.5 M	$ 0	$ 22.5 M
Eastern		Due	60	36	$ 81,800	$ 31.7 M	$ 40.4 M	$ 72.1 M
		Past Due	2	1	$ 106,600	$ 1.1 M	$ 0	$ 1.1 M
Total Target Lane Miles per Year			887	712		Sub Total ACP Highways =		$ 1,415.4 M
Western	Ramps	Due	35	35	$ 110,800	$ 41.9 M	$ 39.5 M	$ 81.4 M
		Past Due	4	4	$ 145,000	$ 7.1 M	$ 0	$ 7.1 M
		Due	23	16	$ 102,600	$ 15.5 M	$ 23.2 M	$ 38.7 M
		Past Due	1	0	$ 136,300	$ 0.5 M	$ 0	$ 0.5 M
Total Target Lane Miles per Year			63.1	55.9		Sub Total ACP Ramps =		$ 127.7 M

Total ACP Cost $1,543.1 M

1 Target miles per year for Western Regions are based on a total of 451 miles with an average pavement life of 14.9 years.
Target miles per year for Eastern Regions are based on a total of 436 miles with an average pavement life of 10.5 years.
Target miles per year for ramps are based on a total of 835 miles using the average of western and eastern pavement lives.
Target miles per year with Performance Grade binders is a result of the expected pavement life increase for using performance grade asphalt. Note: Western Regions target miles do not change.

2 Cost for remaining years of 20 year plan = (Due cost/lane mile) x (due + past due target miles) using target miles with Performance Grade asphalt.

Portland Cement Concrete Pavement (PCCP) Estimate

Region	Surface Type	Project Type	Target Ln-Mi[1] per Year	Cost per Ln-Mi	Cost for First[3] Ten Years	Cost for Second[4] Ten Years	20 year Cost
All	PCCP	Dowel Bar Retrofit	57.1	$ 300,000	$ 12.0 M	$ 5.1 M	$ 171.2 M
All	PCCP	Full Replacement	57.1	$ 500,000	$ 8.6 M	$ 20.0 M	$ 285.4 M

Total PCCP Cost $456.6 M

3 Costs for first ten years estimated as 70 percent dowel bar retrofit and 30 percent full replacement.

4 Costs for second ten years estimated as 30 percent dowel bar retrofit and 70 percent full replacement.

Pavement Preservation Estimate (continued)

Bituminous Surface Treatment (BST) Estimate

Region	Surface Type	Project Type	Target Ln-Mi per Year	Cost per Ln-Mi	20 Year Cost
All	BST	BST	673.7	$ 12,000	$ 161.7

Total BST Cost	**$161.7 M**

ACP Thin Overlay Estimate

Region	Surface Type	Project Type	Target Ln-Mi per Year	Cost per Ln-Mi	20 Year Cost
All	ACP Thin	ACP Thin	17.8	$ 50,000	$ 17.8 M

Total ACP Thin Cost	**$17.8 M**

Total – All Surface Types

Total	**$2,179.1 M**

Safety and Drainage Restoration

Add 12 percent to ACP, PCCP, BST Total	**$261.5 M**

Other P1 Costs

Crumb Rubber (this item has been deleted)	$0
Weigh Stations	$5.0 M
Research	$6.3 M
Pavement Management System	$8.5 M
Pits and Quarries[5]	$25.0 M
Sub-Total other P1 Costs	**$261.5 M**

5 Pits and Quarries revised 3/6/96 per Steve Baxter to fund every biennium rather than eliminate after the first two biennium as originally set up.

Total P1 System Plan Estimate

Grand Total P1 Estimate $ 2,485.4 M

Note: All data is in 1997 Dollars.

Generic One Mile ACP Paving Estimate Summary

Paving Costs Only – Safety/Drainage Restoration not included

Roadway Width		Western	Eastern
	Rural Pavers		
32 feet	Two Lane Due	$ 89,300	$ 80,700
32 feet	Two Lane Past Due	$ 119,800	$ 107,800
76 feet	Multi Lane Due	$ 86,900	$ 78,300
76 feet	Multi Lane Past Due	$ 114,400	$ 105,800
	Urban Pavers		
38 feet	Two Lane Due	$ 129,600	$ 101,300
38 feet	Two Lane Past Due	$ 163,500	$ 135,200
64 feet	Multi Lane Due	$ 110,800	$ 81,800
64 feet	Multi Lane Past Due	$ 135,600	$ 106,600
	Ramps		
24 feet	Due	$ 10,800	$ 102,600
24 feet	Past Due	$ 145,000	$ 136,300

NOTES: 1). All $s have been rounded up to an even $100
2). Roadway widths include lanes and shoulders

Past Due Repair Cost Analysis

Repair Cost	Years Past Due	Lane Miles	Percent of Total
25%	Less than 3 years	660	74%
50%	3 to 6 years	177	20%
100%	Greater than 6 years	57	6%
	Total Past Due Miles	894	
	Weighted Average Repair Cost =	35%	
	For Estimate Purpose Assumed =	40%	

Repair cost is an assumption that as the number of years past due increases, paving and traffic control costs would increase by the above percentages. Number of past due miles is based on 1995 WSPMS.

Distribution of ACP Lane Miles

Region	Rural-2	Rural-M	Urban-2	Urban-M	Ramps	*Total	% of Total
Northwest	1050	194	240	1123	321	2607	25%
North Central	589	333	37	88	31	1047	10%
Olympic	1236	323	147	621	167	2327	22%
Southwest	1226	231	63	240	96	1760	17%
South Central	535	330	34	217	151	1116	11%
Eastern	892	498	30	231	70	1652	16%
Total Lane Miles	5528	1910	550	2519	835	10507	
% of Total ACP Lane Miles	53%	18%	5%	24%			
% in Western Regions	64%	39%	82%	79%	70%	64%	
% in Eastern Regions	36%	61%	18%	21%	30%	36%	

Note: Ramps includes crossroads but does not include collector distributors (CD). These are included in highway lane miles.

Total of 10,507 miles does not include ramp lane miles.

Distribution of Yearly Target Miles by Highway Category – Western/Eastern

	Western Regions				Eastern Regions			
Highway Type	Total	Percent of Total	Target Miles per Year	Target Miles w/PG	Total	Percent of Total	Target Miles per Year	Target Miles w/PG
Rural 2 Lane	3512	52%	237	237	2017	53%	230	138
Rural 4 Lane	746	11%	50	50	1162	30%	133	79
Urban 2 Lane	449	7%	30	30	101	3%	12	7
Urban 4 Lane	1984	30%	134	134	536	14%	61	37
Totals =	6693	100%	451	451	3814	100%	436	260

Total Combined Target Miles =	887
Total Combined Target Miles w/PG =	712

Projected Past Due ACP Lane Miles for 99-01 Biennium

Region	Total ACP Lane Miles	Past Due Miles < 3 yrs.	4 to 6 yrs.	> 6 yrs.	Total PD	% past Due
Northwest	2663.7	179.9	64.2	26.96	271.1	10.2%
N. Central	1018.0	43.1	5.5	1.46	50.0	4.9%
Olympic	2520.7	277.2	74.3	21.34	372.9	14.8%
Southwest	1759.4	115.8	31.2	0.15	147.2	8.4%
S. Central	1324.3	22.6	0.7		23.3	1.8%
Eastern	1682.0	21.8	1.2	6.76	29.8	1.8%
Totals =	10968.0	660	177	57	894.2	
% of total past due miles		74%	20%	6%		

% past due in Western Regions	11.4%
% past due in Eastern Regions	2.6%

Notes from Pavement Management Office:

Past Due for 1999-2001 Biennium are those projects whose due year is 1997 or earlier.

Based on 1996 Projects Database and CPMS data on 03/10/1997. Includes all roadways in WSPMS.

Total Lane Miles and Predicted Target Lane Miles

Region	ACP Total	ACP Target	BST Total	BST Target	ACP Thin Total	ACP Thin Target	PCCP Total	PCCP Tar
Northwest	2778.0	186.4	0.0	0.0	77.0	6.4	848.6	2
North Central	1315.0	125.2	1151.0	191.8	4.0	0.3	5.1	
Olympic	2217.0	148.8	312.0	52.0	99.0	8.3	175.8	
Southwest	1727.0	115.9	406.0	67.7	18.0	1.5	200.4	
South Central	1338.0	127.4	715.0	119.2		0.0	879.7	2
Eastern	1921.0	183.0	1458.0	243.0	15.0	1.3	173.5	
Totals =	11296.0	886.8	4042.0	673.7	213.0	17.8	2283.0	5

Western Regions Total Target	451
Eastern Regions Total Target	436

Notes: Lane miles from Robyn Moore's BST/ACP Conversions spreadsheet (does not include frontage roads and r

ACP target miles are based on Eastside and Westside average pavement lives. PCCP target miles are base of 40 years. BST target miles are based on a statewide average life of 6 years. ACP Thin overlay target ba 12 years.

Predicted ACP Target Lane Miles with use of PG Binders

Region	ACP Total	ACP Target	BST Total	BST Target	PCCP Total	PCCP Target
Northwest	2661.9	178.6	192.5	32.1	848.6	21.2
North Central	1100.3	73.4	1623.5	270.6	5.1	0.1
Olympic	2324.9	156.0	303.5	50.6	175.8	4.4
Southwest	1736.7	116.6	413.5	68.9	200.4	5.0
South Central	1185.4	79.0	867.7	144.6	879.7	22.0
Eastern	1620.5	108.0	1519.6	253.3	173.5	4.3
Totals =	10,629.6	711.6	4920.2	820.0	2283.0	57.1

Western Region Total Target Miles	451
Eastern Region Total Target Miles	260

Notes: Lane miles from 9/11/95 TRIPS Mileage Report (does not include frontage roads and ramps). Due to acco lane miles do not match total from highway categories shown above.

ACP target miles are based on eastside and westside average pavement lives. PCCP target miles are base average life of 40 years. BST target miles are based on a statewide average life of 6 years.

20 Yr. P1 Biennial Distribution by Region

	System Plan Year							
	1-2	3-4	5-6	7-8	9-10	11-12	13-14	1
	Biennium Year							
Region	**99-01**	**01-03**	**03-05**	**05-07**	**07-09**	**09-11**	**11-13**	**1**
Northwest	$67.3 M	$67.3 M	$67.3 M	$67.3 M	$67.3 M	$70.4 M	$69.7 M	$
N. Central	$29.0 M	$29.0 M	$29.0 M	$24.8 M	$20.7 M	$20.7 M	$20.7 M	$
Olympic	$42.9 M	$42.9 M	$42.9 M	$42.9 M	$42.9 M	$42.8 M	$42.0 M	$
Southwest	$32.6 M	$32.6 M	$32.6 M	$32.6 M	$32.6 M	$33.1 M	$32.8 M	$
S. Central	$47.5 M	$47.5 M	$47.5 M	$43.7 M	$39.8 M	$43.7 M	$43.7 M	$
Eastern	$44.9 M	$44.9 M	$44.9 M	$39.3 M	$33.7 M	$34.4 M	$34.4 M	$
OSC	$4.5 M	$4.5 M	$4.5 M	$4.5 M	$4.5 M	$4.5 M	$4.5 M	
All	$268.6 M	$268.6 M	$268.6 M	$255.0 M	$241.3 M	$249.7 M	$247.8 M	$2
								20 Yr. Sys

All Dollars are in 1997 million's

Note: The 20 yr biennial distribution total does not match the 1995 P1 estimate. The reason is the 20 yr. biennial is c region vs. the 1995 P1 using Westside and Eastside averages for target miles and pavement lives.
The 20 yr. biennial $s should probably be used for the System Plan P1 estimate.

20 Yr. P1 Distribution by Pavement Type by Region

	Northwest	N. Central	Olympic	Southwest	S. Central	Eastern	Tot
ACP	$386.7 M	$158.5 M	$296.9 M	$219.6 M	$168.7 M	$234.0 M	$1,4
ACP (Ramps)	$49.3 M	$4.8 M	$26.5 M	$14.6 M	$23.9 M	$10.9 M	$1
PCCP	$169.7 M	$1.0 M	$35.2 M	$40.1 M	$175.9 M	$34.7 M	$4
BST	$0.0 M	$46.0 M	$12.5 M	$16.2 M	$28.6 M	$58.3 M	$1
Safety/Drainage 12%	$73.5 M	$25.3 M	$45.5 M	$35.0 M	$47.7 M	$40.7 M	$2
Totals =	$679.1 M	$235.7 M	$416.6 M	$325.5 M	$444.8 M	$378.6 M	$2,4

ANNEX C

NEW TECHNOLOGIES AND RESEARCH ISSUES

Whitetopping

Whitetopping is a concrete overlay of an existing asphalt concrete pavement. When cost effective, the concrete overlay is placed over severely rutted and/or distressed (cracked) asphalt pavements. When designing a whitetopping overlay, the pavement thickness is based on the support of the underlying pavement, the environment, and the level of truck traffic that the roadway must carry. Whitetopping thickness can be as thin as two inches and as thick as a newly constructed concrete pavement (11 to 12 inches). Thin concrete overlays (two to four inches) are normally referred to as ultra-thin whitetopping (UTW). In order to ensure the performance of the UTW, the following characteristics must occur: adequate bond between the UTW and the existing asphalt concrete pavement, short joint spacing (two to five feet), and existing asphalt concrete thickness must be more than four inches. Performance has shown that UTWs are most appropriate for low volume roadways (200 to 300 trucks per day or less than 1,000,000 equivalent single axle loads). In Washington state, concrete pavements have performed exceptionally well considering the length of service (over 60 percent of the concrete pavements are 25 years and older) and the significant increase in truck traffic (two to five times greater than originally designed). It is estimated that a UTW, when appropriately designed, can obtain a 10 to 15 year performance life. Thicker concrete whitetopping (9 to 12 inches), when designed appropriately, can perform 30 to 40 years. An important aspect of whitetopping, or any other pavement design feature, is to ensure adequate performance and cost effectiveness.

Hot In Place Recycling

Hot In-Place Recycling (HIR) involves softening of the existing asphalt pavement by heating, then milling/scarifying to a depth of one to four inches, adding additional material (asphalt and aggregate) as needed, thoroughly remixing, leveling, and compacting the milled/scarified material back onto the existing roadway. This process is completed in one pass, shipment of material to a plant is not required (all work is completed on the roadway), and therefore has an average production rate of two lane miles per day. This process has several other benefits, such as recycling the existing asphalt concrete surface minimizes the demand on oil and aggregate sources, minimal motorist inconvenience, and provision of a potential cost savings of 10 to 50 percent. This is based on initial cost only of one inch of HIR compared to one inch of virgin asphalt concrete; long term performance data is very limited. However, there are also several limitations. This process is unable to repair underlying base and or pavement failures; the structural capacity of the roadway can only be enhanced through the addition of a structural overlay; major improvements to substandard mixtures cannot be addressed (flushing, stripping, raveling, etc.); the existing pavement thickness must be at least one inch thicker than the depth of recycle; the presence of an excessive number of obstructions (manhole covers, grates, etc.); and excessive amounts of patching and crack sealing are not recommended for this process due to reductions in production rates.

Considering not only the experience obtained from other states and the British Columbia Ministry of Transportation but also the experience WSDOT has obtained from the construction of a HIR project, the success of the HIR process is extremely dependent on the existing conditions of the pavement to be recycled. The HIR process is not applicable to all projects; detailed pavement condition surveys and mix design are required for each project.

Based on the results of in-service pavements, the expected service life of the HIR process without an overlay and with the current HIR equipment should be approximately six to eight years. If the HIR material is overlaid and assuming that the recycled material is a quality product, the performance of the pavement section will be dependent on the performance of the overlay (10 to 15 years). HIR may be more appropriate as a maintenance treatment.

Superpave

The Strategic Highway Research Program (SHRP) was established by Congress in 1987 as a five-year, $150 million product-driven research program to improve the quality, efficiency, performance, and productivity of our Nation's highways and to make them safer for motorists and highway workers. It was developed in partnership with the States, the American Association of State Highway and Transportation Officials, the Transportation Research Board, Industry, and the Federal Highway Administration.

SHRP research focused on asphalt (liquids and mixtures), concrete and structures, highway operations, and long-term pavement performance (LTPP). The final product of the asphalt program was the development of Superpave (Superior Performing Asphalt Pavements). Superpave represents an improved system for specifying the components of asphalt concrete, asphalt mixture design and analysis, and asphalt pavement performance prediction.

Superpave mix design consists of the following: selection of materials, aggregate structure, and asphalt binder content, along with the evaluation of moisture susceptibility. Binder selection is based on environmental data and aggregate selection is governed by criteria based on traffic level. Prior to the advent of Superpave, the selection process was primarily based on experience. Superpave allows the selection of the asphalt binder and mixture to be designed on anticipated climatic conditions and truck loading levels.

Accelerated Pavement Testing

FHWA has provided funding for the establishment of a test track (WesTrack) at Reno, Nevada. Extensive testing has been conducted on 26 asphalt concrete pavement sections associated with SHRP Superpave. The test track was built to continue the development of performance-related specifications for asphalt concrete construction. Many of the variables associated with asphalt concrete were evaluated (changes in air voids, aggregate structure, and asphalt content), loaded with accelerated truck traffic (approximately ten years of Interstate traffic was applied in a two-year period), and then evaluated. The intent of this initial study is to determine the various effects of construction on the overall performance of the asphalt concrete pavement. The project is approximately halfway through the evaluation process, and a formal report of results and findings will be forthcoming. In the near future, the facility will also be able to test specific pavement sections for the states. The cost per section is $100,000 - $300,000.

The Minnesota Department of Transportation (MnDOT) has also constructed a roadway test facility named Mn/Road. This facility was constructed to investigate road design and procedures, roadway materials, and the effects of traffic loads and weather on the performance of pavements. A few of the main research objectives of Mn/Road are to evaluate the effects of heavy vehicles on pavement performance, evaluate the seasonal change in paving materials, and improve the design and performance of low-volume roadways. This project was constructed in 1990 and is expected to last at least 20 years.

There are other similar accelerated testing facilities in the United States and abroad. All have an ultimate goal of improving the design, construction, performance and safety of the roadway network.

Long Term Pavement Performance Program

The Long-Term Pavement Performance (LTPP) program is a 20-year study initiated in 1987 as part of SHRP to test sections of in-place pavements subjected to traffic loads and environmental conditions. These 2,200+ test sections at nearly 1,000 locations across North America (US and Canada) have a goal to extend the performance life of pavements by improving pavement design and to understand pavement response as affected by truck loadings, the environment, subgrade soils, and maintenance practices. (WSDOT has 21 different sites as part of the LTPP program). These sites are monitored yearly for pavement condition such as cracking, patching, etc., pavement profile and rutting, seasonal temperatures, and structural strength. The LTPP program is a very extensive pavement test. Several recommendations have already come from LTPP, and many more are anticipated over the next ten years.

International Developments

Large stone mixes, stone mastic asphalt, and the South African G1 base are current examples of pavement technology developed outside the US which hold potential for WSDOT application. WSDOT continues to evaluate these and other developments for application in the state highway network.